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Controlled nuclear fusion, energetic utopia

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Abstract
Through a comprehensive analysis, accentuated by theoretical scientific and economic aspects, using a basic physical approach about compressed air, an observation about magnetic field plasma compression is made. This observation, about the attempt to use the magnetic field confinement in controlled nuclear fusion, is related to the fact, aside from several technological and economic problems, that a magnetic field cannot properly confine ionized gas; in the best case it can only constrict the movement of ions and electrons. The analysis results leave little confidence that the conventional method intended to achieve the goal of controlled nuclear fusion could succeed. Also facing this complex scenario plenty of technical and economic difficulties; we try to offer an alternative method that could provide hope for the commercial use of nuclear fusion reactions.

Keywords: nuclear fusion, magnetic confinement, tokamaks, cold fusion, energy production

1. Introduction

On 8 May 1946, Sir George Paget Thomson and Moses Blackman applied for a patent for a device based on electrical discharges in gases that would supposedly constitute a nuclear fusion reactor. This device is the first formal proposal for a controlled nuclear fusion reactor, which, in practice, did not work [1].

On 24 March 1951, before a select audience of officials and journalists, Juan Domingo Peron (then president of Argentina) made an announcement that quickly spread worldwide. "On February 16, 1951, in the pilot atomic power plant on the island of Huemul, San Carlos Bariloche, were carried out thermonuclear reactions under controlled conditions in technical scale". [2-4] Confident and categorical, Juan Domingo Peron explained that the United States, Britain and the Soviet Union followed the way of nuclear fission of heavy atoms such as uranium isotope 235 or plutonium 239. Then, the president presented to the audience Professor Ronald Richter, a 42-year-old Austrian nationalized Argentine and Huemul project manager, who confirmed the assertions of Peron: "I am interested in affirming that this is not a copy from abroad. It is a completely Argentine project. What Americans get at the time of the explosion of a hydrogen bomb; we in Argentina have done it under control conditions and in the laboratory" [2-4].

Unfortunately, this announcement was just that, and could not be backed up with experimental facts [2-4].

On 23 March 1989 at a press conference at the University of Utah in the United States, two researchers, Martin Fleischmann and Stanley Pons, announced they had produced nuclear fusion reactions sustained in a small laboratory vessel with deuterium trapped in platinum and palladium electrodes. This phenomenon was named cold fusion. The news spread worldwide quickly, generating much alarm in the scientific community at the time. The surprise and amazement of researchers using the large machines for plasma confinement was huge. Something has happened and the researchers were surprised. The announcement claimed that the crystal lattice of certain materials could under the right conditions arrange to produce deuterium fusion reactions [5-7]. What had not been achieved with large plasma machines (involving millions of dollars) allegedly was possible in a container that could be a small kitchen glass; and what's more, since then the phrase "cold fusion" would be banished for all self-respecting scientists [8].

These three events: the patent of a controlled nuclear fusion reactor; the announcements by Juan Domingo Peron; and Fleischmann and Pons certainly are milestones in the history of the development of controlled nuclear fusion research. A newspaper ad cannot be considered part of a scientific report because the scientific method requires the participation of the scientific community rather than press readers for a true scientific announcement to be issued. However, these events awakened interest in governments and in the scientific community of some countries causing them to intensify scientific research in this area of knowledge [9-12]. Also, this was an important part of the glimpse into the great difficulties that research into controlled nuclear fusion has faced.

Unfortunately, these projects and several current projects, including the International Thermonuclear Energy Reactor (ITER) project, are still far from yielding the predicted results, so the goal of using commercial fusion is still between 20 and 50 years in the future. This period of time, several decades for the goal, has been repeated many times in the history of research on controlled thermonuclear fusion [13, 14].

The big interest that controlled nuclear fusion has raised since 1946 is the claim that it would be a source of almost inexhaustible energy, environmentally sound, and inexpensive, since water would be its raw material, accessible virtually to all countries [15, 16]. A cubic metre of water contains about 34 grams of heavy hydrogen (deuterium) that under nuclear reactions could be equivalent to about three hundred thousand litres of oil. Unfortunately, the commercial exploitation of electricity product of controlled fusion reactions has been hampered by huge challenges that are not only technological and theoretical, but economic and even political [13-15].

Initially, it seemed that if the technology of the atomic bomb could be quickly applied to produce the fission reactor, the hydrogen bomb technology would also be applied to produce a controlled nuclear fusion reactor. The reality turned out to be very different, and immediately there appeared resistance to domestication of nuclear fusion reactions. The goal of commercial use of fusion reactions is permanently perceived, perhaps too far in time towards the future [12, 13, 15]. Magnetic confinement, which involves the physics of plasmas (ionized heavy hydrogen), supposedly resulted in slow, but steady progress in the "battlefield" of controlled fusion. This battlefield is usually shown in the plasma density diagram versus plasma temperature × confinement time [13]. In this context, it is said that the experimental results have progressed by a factor of a million; however, this supposed progress has been questioned in different scenarios and forums [17, 18].

In 1991, energy from controlled nuclear fusion based on a mixture of deuterium and tritium was achieved for the first time in the JET European project based in Britain and currently the largest tokamak in the world in operation, energy from fusion reactions released 16 MW and consumed 25 MW. However, it is necessary to develop a reactor that emits more energy than it consumes and can produce a self-sustaining reaction: burning plasma. Much of the nuclear fusion community considers that the most likely way to achieve this is through a much larger reactor.

In 1988 an international group of scientists concluded the design of the first international tokamak experimental reactor (ITER), whose initial cost of 6 billion US dollars, spooked some politicians. In an atmosphere of confrontation between President Clinton and the Republican Congress, the United States decided to abandon the project in 1998, despite a prior agreement between Presidents Reagan and Gorbachev of the former USSR. With a reduced 3 billion dollar budget, scientists from Japan, Russia and Europe conceived the ITER-FEAT or Advanced Tokamak Fusion Energy version, which should be sufficient to study the plasma burning, producing 1500 MW net. International fusion research focuses its attention on two alternative projects: FIRE in the United States and IGNITOR in Italy, both based on the concept of bringing the combustion conditions of plasma from higher energy concentrated in lower volume tokamaks.

Even today nuclear fusion energy cannot be obtained on a commercial scale. Some researchers believe that it will be necessary to continue to wait a period of between 20 to 50 years to see that dream realized. Others doubt that it can be achieved at all [17, 18].

The 1991 Nobel laureate in Physics, Pierre-Gilles de Gennes, once said about nuclear fusion: "We say that we will put the sun in a box. The idea is attractive; the problem is that we do not know how or what material to use for the box" [19].

This paper aims to show that the outlook for the future of controlled thermonuclear energy is not only perceived to be extremely complicated but, there is also the possibility that this way of looking for domestication of nuclear fusion energy, through plasma physics and magnetic confinement, will not be possible to achieve at all.

2. The Problem

When a fuel, such as butane gas, is used in combustion a match is required to start the ignition. In the case of gasoline in internal combustion engines in most cars, the match is the spark plug that, through an electrical discharge, ignites the gasoline.

In the case of nuclear fuel a mixture of deuterium and tritium are used; perhaps in an unfortunate manner for this mixture the matchstick chosen was the thermal energy of the particles, which in turn temperature must be increased to extremely high levels. The ionised mixture of these two isotopes of hydrogen (D + T) constitutes the fuel forming high temperature plasma [20].

Increasing the density, heat, and at the same time confining the plasma at temperatures exceeding 100 million Kelvin degrees has proved to be an extremely difficult task. Always, the plasma prevent itself from being heated and cannot be properly confined. This behaviour of the ionized gases has determined the major issues surrounding controlled nuclear fusion. After great efforts and progress that have been made, much of the scientific community believes that the achievement remains several decades into the future [17, 18].

Figure 1 shows a schematic cross-section of a possible configuration of a controlled nuclear fusion reactor.

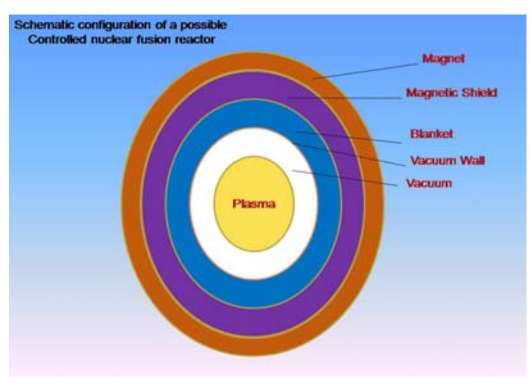

Fig 1: The schematic cross-section of a proposed fusion reactor

Confining plasma with densities of 10^{20} particles per $m^3$and temperatures of more than 100 million Kelvin degrees for a long enough time has been virtually impossible. There are substantial technological and scientific reasons why this task has not been achieved. Some call this the problem of plasma transport. This problem has baffled most of the scientific community [17, 18]. This will immediately be analysed, though perhaps in a very conceptual way.

According to some sources, in the past sixty years governments have spent about 20,000 million US dollars on fusion research and it seems that success is no closer than it was at the beginning [17, 18]; except in the sense that we have learned more about why things do not work as initially was thought. Doubtless, this approach exists, although the economic costs also have a relatively large specific weight [21, 22]. It has been argued that it is because the magnetic field used in experiments does not confine the plasma; it only constrains the movement of some of the particles. This sets up a reality that we will try to make clear with a basic physical approach with a fundamental further interpretation.

Here, it is appropriate to note that the problem that exists today in the search for the domestication of controlled nuclear fusion has also existed with other scientific and technological applications. At the time they were described as "scientific and technological triumphs", however, ultimately they proved failures, not so much for scientific reasons but technological, political, or economic [21, 22]. Below is a list of examples of the aforementioned supposed technological and scientific achievements.

The Zeppelin: This motor-powered air ship was a self-propelled dirigible. The lift is achieved by tanks filled with a gas of lower density than the surrounding atmosphere. The LZ 129 Hindenburg, German Zeppelin airship type was destroyed by fire as it landed in New Jersey on 6 May 1937. The crash killed about 30% of the occupants, which fortunately was not many. To some extent this accident influenced its abandonment for commercial application.

The Franco British Concorde is a supersonic aircraft that had to be landed after having suffered a fatal accident for the occupants in July 2000 and after economic problems. It was designed for a little over 100 occupants, however made flights with only 20 people on board. The approximate price of a New York–London round-trip was 10,000 US dollars. The Concorde was obliged to fly away from the cities due to the tremendous noise it produced, breaking windows.

Without doubt there have been many other failed scientific projects as the search for the panacea, the autonomous flight of man, etc. More modern projects can be included in this list of examples of scientific and technological triumphs; as they can be debatable: the Higgs boson and the announcement that gravitational waves were found. Checking these findings for many other scientists, as it is part of the scientific method, seems almost impossible.

3. The problems inside the problem

The existing problems around the magnetic confinement of plasma are broad and disturbing, however, the problems that are considered most important are mentioned below:

- Neutron flux. In a fusion reactor the neutron production will be abundant and necessary, however it is also detrimental. Nuclear fusion reactions chosen for first generation fusion reactors produce neutrons that must be stopped in a reactor cover. In this cover the neutron energy is transformed into heat energy. This intense neutron flux generates two major problems for the structures of the reactor. They cause structural damage and the structure itself becomes radioactive. This implies that the structures have to be changed periodically and with additional difficulty since it becomes radioactive. This periodic replacement in a fusion reactor increases the expensive maintenance costs of the power plant [17, 23].
- Energy production. In a nuclear fusion plant, it is necessary to generate large amounts of energy; along with this large amount of energy comes the possibility of damage in the reactor's first wall. Therefore, some kind of protection for the reactor structure must be added. Elementary protection maintains the plasma, being extremely hot, away from the walls. Trying to separate the plasma from the first wall means adding a limiter, which involves additional complications related to removing energy from the peripheral plasma. Diverters are the elements of the reactor structure that handle this removal of energy. They must have the separation capacity and the ability to handle that separated amount of energy. The scientific community is trying to resolve these troubles regarding materials science [17, 23].
- Low energy density. A fusion reactor based on the magnetic confinement of D + T plasma will have a relatively low energy density. Part of this problem is due to the high neutron flux that the first wall receives, which requires that this bombardment be distributed in a relatively large area, i.e., the first wall and other components must be large, so that neutron incidence by unit area is relatively small. Therefore, compared with a fission reactor, power density is extremely small in a magnetic fusion reactor [17]. Thus, the reactor size will be relatively large in order to maintain adequate efficiency. This low energy density and the relatively large size of first wall of the reactor results in raised energy production costs. This low energy density involved in the production costs can be extremely limiting, in the search for the domestication of the fusion reactions.
- Plasma disruptions. Perhaps the most serious problem in magnetic confinement of plasma is related to disruptions of the plasma current. Sometimes, the driving plasma current channel is interrupted and all the plasma energy tends to go towards the machine walls. Strategies to control the disruptions are used once there is evidence of any disturbance, in some cases using a kind of extinguisher. The extinguisher is injected to absorb much of the energy of the discharge, such as an inert gas or small crystals of ice. A fusion reactor that includes an extinguisher of this nature, to avoid disruptions damaging walls, will undoubtedly further increase problems of intermittency making it difficult to restart the normal operation. This also tends to increase the costs of the installation to a degree that could be prohibitive, as the efficiency of energy production significantly is reduced [24-26].

4. A physical problem of transcendence

The problem of transcendence in plasma magnetic confinement configurations is the relative physical equilibrium that is implicated in the generation of disruptions. This physical equilibrium commonly is specified through the balance of forces in the plasma magnetic confinement system [27]. However, the problem often has a slightly ambiguous approach and usually is introduced through the Grad-Shafranov equation [27-29].

The Grad-Shafranov equation is a Poisson type equation i.e., it is an elliptical partial differential equation. Of course, it depends strongly on the initial conditions and can be treated as a Cauchy problem. Usually, it is numerically integrated [29].
In particular, for the case of tokamaks, before specifying the balance that can be achieved in this type of machine, it should be clarified that the balance in this case is configured as an unstable equilibrium. In other words, it is said that the unstable equilibrium in magnetic confinement is like the case of a tightrope walker, any change in the state of the system increases the unbalance. In the case of stable equilibrium, when the system state is out of balance the position is varied and a restoring force appears that restores the initial conditions. Even in these circumstances of instability, it is typical to describe the force balance in tokamaks as follows [28, 29]:
The calculation of the free boundary MHD (Magneto-Hydrodynamic) equilibrium is axially symmetrical and forms the basis of the study of the dynamics of plasma in a tokamak, allowing the prediction of fields and currents from the interactions of the plasma with the magnetic field in a particular configuration.
The most common function to describe this balance is the poloidal magnetic flux which satisfies $\bar{B} \bullet \nabla\psi = 0$, that is, in a cylindrical coordinate system, whose Z axis coincides with the machine toroidal axis, the magnetic field is described as

$$B_R = -\frac{1}{R}\frac{\partial\psi}{\partial z}, \text{ and } B_Z = \frac{1}{R}\frac{\partial\psi}{\partial R}, \quad (1)$$

Thus, with the equilibrium equation $\bar{J}\Box\bar{B} = \nabla p$ and the toroidal component of the Ampere equation $\mu\bar{J} = \nabla\Box\bar{B}$, we have

$$R\frac{\partial}{\partial R}\frac{1}{R}\frac{\partial\psi}{\partial R} + \frac{\partial^2\psi}{\partial Z^2} = -\mu R J_\phi \quad (2)$$

inside the plasma and

$$R\frac{\partial}{\partial R}\frac{1}{R}\frac{\partial\psi}{\partial R} + \frac{\partial^2\psi}{\partial Z^2} = 0 \quad (3)$$

outside the plasma.
The elliptical expression (2) is the known Grad-Shafranov equation and the inhomogeneous term may be related to the plasma pressure [29]

$$-\mu R J_\phi(\psi, R) = \mu\left[R^2\frac{dp}{d\psi} + \frac{dg}{d\psi}\right], \quad (4)$$

where

$$g(\psi) \equiv R^2 B_\phi^2/2\mu. \quad (5)$$

Given the non-linear nature of the Grad-Shafranov equation, the solution to the problem is generally not easy to achieve. Although some analytical solutions are possible for special cases such as that of large aspect ratio, most of the solutions to the Grad-Shafranov equation are found numerically. That is why, around the world, specific codes are continuously being developed to meet the requirements of each particular tokamak [27-29]. The types of numerical solutions to the Grad-Shafranov equation can be classified into three groups [29]:

- Direct solutions in which it ψ is determined, given J_ϕ.
- Inverse solutions where $\bar{J}$ is found for the tokamak coils, given a desired balance.
- Interpretative solutions in which ψ and J_ϕ are determined from experimental measurements of ψ in a finite number of points where J_ϕ can be expressed according to equation (4).

Specifically, equation (2) applies to the case when $\psi > \psi_L$ and equation (3) applies when $\psi < \psi_L$, where

$$\psi_L \equiv max\{\psi(R,z)|(R,z)\varepsilon C_L\}. \quad (5)$$

C_L Represents the tokamak limiter points and ψ_L defines the free boundary or plasma-vacuum interface.
Thus, numerical solutions generally are obtained by relating the flux to the position and intensity of the coil current, taking into account the unstable equilibrium of this type of magnetic confinement machine
In trying to understand the plasma-magnetic field interaction, this type of numerical study of equilibrium in tokamaks is commonly performed. However, the basic problem remains, i.e. the existing instabilities generating unbalance on the fragile equilibrium in these confinement machines [30, 31]. This problem persists, due to an underlying cause that has to do with a fundamental physical problem that could be considered of extreme complication.
What is the basic physical problem underlying the plasma-magnetic field interaction?

Look at it this way
The tokamak equilibrium problem is mainly related to the magnetic pressure generated on the plasma. Pressure is defined as the force per unit area. Anywhere a magnetic field exists, there is also a resulting magnetic pressure identical to the magnetic energy density [32]:
$\mathbb{E}_B = \mathbb{P}_B = 3\varepsilon_0 B^2/2.$
The energy density $\mathbb{E}_B$ and energy in general, can perform work, primarily because it is identical to the pressure (force per unit area). There always exists a difference in pressure on the body surface, and acceleration appears. In principle, this magnetic pressure can compress and confine the plasma. Problems arise from something very basic: The efficiency to squeeze up of this pressure in the plasma compression is very low. The efficiency of the magnetic pressure to compress the plasma is measured by the beta factor defined as [33]
$\beta = {}^{\mathbb{P}_P}/_{\mathbb{P}_B}.$
This factor is the ratio of plasma pressure $\mathbb{P}_P$ divided by the magnetic pressure. This factor is, in practice, relatively small, in fact it is always less than 30% [33]. The reason for this result comes from a fundamental characteristic involving the properties of the magnetic field and the particular characteristics of the plasma instability [17]. The statement is very strong and requires, of course, a physical justification. The physical explanation can be complicated in many ways; however, we have chosen an example from everyday life that many of us can easily understand:
In an air pump, one with which you attempt to inflate the rubber tube of a bicycle wheel, a piston within the cylinder moves, whose structure may vary, however it is essentially a plunger made of solid material with certain mechanical strength. A schematic conception is shown in Figure 2. The air pressure at the end of the cylinder can be increased by sliding the piston to the left and generally this pressure is sufficient to inflate the tyre tube. It may be the case that excessive pressure at the end of the air pump results. This could damage the piston or the piston moving within the cylinder could damage the cylinder itself. However, in the case of compressed air, the air only reacts against the

compression to resist being compressed, enhancing its pressure.

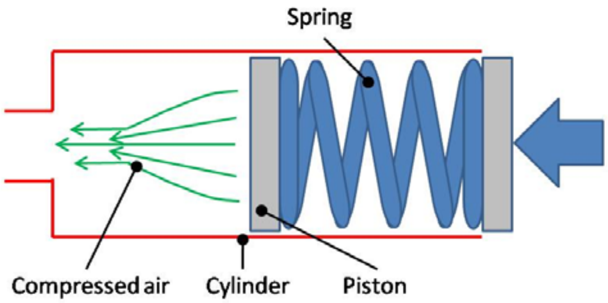

Fig 2: A diagram of an air pump compressing a volume of air. This only generates a simple compression, and the air volume just enhances its pressure.

In the case of a magnetic field compressing plasma, the physics and the apparatus are fundamentally different. Now the piston would be represented by a magnetic field and the air would be replaced with an ionized gas, the plasma. Here, the instrument we intend to push, or compress, is made of a very special essence. Now, the compressor is not a solid material but something more tenuous and ethereal with an inconsistent structure, the applied magnetic field. See Figure 3.

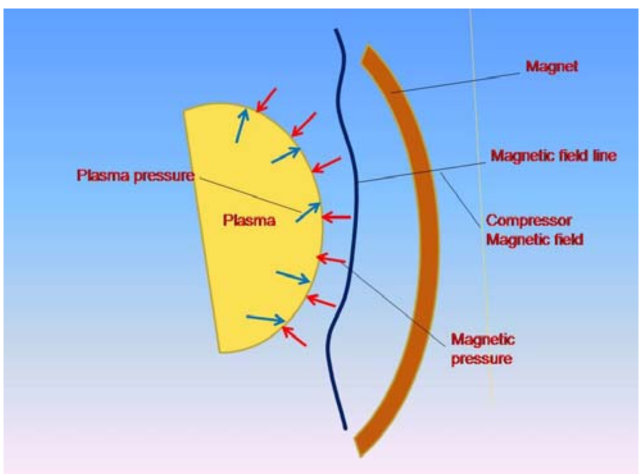

Fig 3: A diagram displaying the plasma and the compressing magnetic field. Now the magnetic field lines constitute the compressor piston and generate the magnetic pressure stated against the plasma pressure.

Moreover, in this case the plasma instead of the previous one defends itself to avoid being compressed in various ways, not only increasing the pressure but generating a corrosive action on the magnetic field. One of the most important ways is that the plasma reacts to compression through instabilities, generating electrical currents which, in turn, generate additional magnetic fields which, through the superposition principle, add to the compressor magnetic field. The result is that the compressor field commonly deteriorates. That is, the plunger (magnetic field) deteriorates relatively easily due to plasma transport and the generation of instabilities which generates electrical currents.

When the compressor field is contaminated with the magnetic field from plasma currents, its compression function deteriorates, producing, among other things, the famous disruptions of the flow of plasma current that breaks the unstable equilibrium that previously existed. This effect turns out to be disastrous for the plasma confinement sought. Disruptions turn out to be one of the most serious problems in the magnetic confinement of plasmas.

Due to the aforementioned reasons, the controlled nuclear fusion could not be obtained by means of magnetic plasma confinement. However, this physical analysis of the fragility that is generated between the magnetic compression and plasma dynamics with a violent response makes it clear that compressing and confining the plasma turns out to be a very difficult problem to solve with the results not clear enough.

Finally, part of the response of the plasma has a caustic effect on the compressor magnetic field; it deteriorates. It could be that the time needed to find an appropriate solution to this problem would be too long. In the meantime, it might be wise to seek a less complicated approach to produce better conditions for nuclear fusion reactions than that generated by the plasma magnetic field interaction.

At this point it may be appropriate to quote Charles Darwin:

"Often ignorance begets more confidence than does knowledge: it is those who know little, and not those who know much, who positively assert that this or that problem will never be solved by science" [34].

5. A possible solution

We will elaborate on at least one other possible solution for the domestication of controlled nuclear fusion.

After this analysis of the fundamental physical problem in the magnetic confinement of plasma, it becomes more important to search for alternatives and new strategies for achieving domesticated fusion energy.

There is confidence among some researchers in the area that there are alternatives to plasma magnetic confinement.

It is argued that the crystal lattice of some materials, such as platinum and titanium, could produce the electric and magnetic field configuration suitable to make easy nuclear fusion reactions possible. The atomic configuration of the crystal lattice, with its electromagnetic fields, could deflect the electron clouds of atoms of deuterium and tritium, allowing their nuclei to be partially bare by the action of the lattice fields and to come close enough to fuse, which thereby could be used to produce energetic neutrons.

This idea, to change the distance between hydrogen nuclei using the electromagnetic fields of the crystal lattice, was alluded to at the same time as the scandal unleashed by the newspaper conference at the Utah University by Martin Fleischmann and Stanley Pons.

Clearly, there were mistakes in making this newspaper announcement at the Utah University instead of a scientific communication and not only that, it is very likely that the data reported by these investigators, Fleischmann and Pons, could not be supported by convincing experimental evidence.

However, it is appropriate to mention here something about a secondary result of scientific research that occurred between some researchers: There is a little known episode, concerning professionalism and rivalry, and some kind of zeal that can exert a decisive influence to discredit not only researchers but a whole field of research on so-called cold fusion. A group of researchers from MIT gave a totally negative assessment of the results reported by Fleischmann and Pons.

The announced "failure to confirm" by the researchers at MIT was taken as one of the three most negative reports weighed against the cold fusion of those early days. The MIT group's report is the first technical reference cited in the DOE (U.S. Department of Energy) Cold Fusion Panel's report. The group that produced this famous report was and still is working in

the field of fusion known as hot nuclear fusion with a very important program for financing tokamaks and other magnetic confinement machines.
There was likely to have been a hint of vindictiveness and ill will in the development of this renowned MIT report against the newspaper announcement of those researchers.
How dare they suggest another way for nuclear fusion reactions instead of the hot nuclear fusion research on large magnetic confinement machines?

At this stage we can recapitulate

- Researchers Martin Fleischmann and Stanley Pons could not proceed properly in their released newspaper ad. There were also mistakes in obtaining the reported experimental data.
- On the other hand, there was a conflict of interest of the MIT group that was responsible for judging the researchers and cold fusion so negatively in those early days.
- Finally, we consider it significant to examine the conclusions about both researchers and the group with conflict of interest, about cold fusion. Also, it is important to indicate and include here some experimental results confirmed by neutron emission.

There are some experiments that have reported possible neutron emission from fusion reactions carried out in the crystal lattice of some materials [35, 36].
In particular, an experiment with varied electrode geometries in which different devices were used and also an experimental procedure, which produced neutron emission, was performed twice [35, 36]. Experiments used titanium electrodes with electrical discharges in deuterium atmospheres. A neutron flux of about 10 ^ 4 and 10 ^ 5 neutrons per square centimetre per second was measured. The experiment always consisted of electric discharges in deuterium atmosphere with titanium electrodes however; the discharge chambers, the electrode configuration, and the used power sources in some cases were different [35].

6. Some final conclusions

The general understanding is that the achievement of the scientific research into controlled nuclear fusion is always a period between 20 and 50 years in the future.
One important conclusion extracted from the controlled nuclear fusion literature is that: while experimental results have improved by approximately a factor of a million, current difficulties in the field are perceived by some researchers to be similar to those at the very beginning [18]. This question has validity: can scientists and engineers make it work at all?
Within the general problem for the commercial application of nuclear fusion, a basic problem is perceived by the scientific community to be insurmountable: the magnetic field does not properly confine the plasma, in the best case; it constrains the movement of ions and electrons.
Another conclusion is that the plasma caustically responds to compression of the magnetic field as explained in Section 4. The problems related to plasma transport and plasma instabilities in response to the magnetic compression, generate in the researchers' disposition, among other things, discouragement and frustration in the best case. The plasma is in unstable equilibrium and the instabilities generated in the magnetic confinement machines seem to some researchers untameable.
A suggested solution is that the field structure of the atomic configuration of the crystal lattice of some materials, such as platinum and titanium, could give better conditions and allow the nuclei to come closer to facilitate the fusion reactions.
A theoretical and experimental research in this direction is perceived as viable and accessible to a number of laboratories without exaggerated costs as has been the case in the construction of large magnetic confinement machines.

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